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(19) (CA) **CANADIAN PATENT** (12)

(54) Method of Remedial Cement Squeezing Using Phenolic-Aldehyde Gels

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ABSTRACT

An improved method is disclosed for remedial cementing operations. A two-stage process is provided wherein a phenolic-aldehyde gelling solution is injected into an area wherein remedial cementing is to be performed to form a gel near the wellbore and cement is sequentially squeezed into the area. This method is useful to seal and thereby prevent loss of cement in fractured, vuggy or highly permeable zones as well as to block small channels in cement behind casing.

METHOD OF REMEDIAL CEMENT SQUEEZING USING PHENOLIC-ALDEHYDE GELS

Field of the Invention

The present invention relates generally to an improved method of remedial cement squeezing. More specifically, the present invention concerns a two-stage method wherein a phenolic-aldehyde gelling solution is injected into an area wherein a remedial cement squeeze is to be performed prior to the cement squeeze operation.

Background of the Invention

For the successful production of a fluid from a subterranean formation by way of a well, it has long been the practice to cement the casing of the well in position. This operation is termed primary cementing. It has also been the practice to use cement as a means of sealing defects in the primary cement sheath around the casing. This treatment, termed remedial cementing, is generally carried out through perforations in the casing. Defects in the primary cement integrity lead to undesired flow of fluids or gas from undesired zones during production and to the loss of fluids to undesired zones during injection. It has traditionally been difficult to perform remedial cementing operations or to merely plug perforations when the formation accessed by the perforations contains vugs, large open fractures or is highly permeable.

The cement employed in cementing operations concerned with control of fluid production from subterranean formations usually consists principally of a hydraulic cement and sufficient water to provide a readily pumpable and flowable composition which becomes, upon setting, a strong monolithic solid. The term, hydraulic cement, as used herein, refers to portland cement, including aluminuous cements which contain a relatively high proportion of tricalcium aluminate, cements which contain a relatively high proportion of calcium sulfoaluminate, and pozzolana cements which contain a relatively high proportion of light weight mineral sources such as fly ash and volcanic rock.

Remedial squeeze cementing is an operation wherein a cement slurry is forced under pressure into a specific point in a well for remedial purposes. The objective is to fill all the perforations or defects in the primary cement sheath (channels) behind casing with cement to obtain a seal between the casing and formation. However, because cement slurry is a suspension having a high viscosity, the cement can only fill the larger channels, leaving the small channels near the wellbore unfilled. As a result, many conventional cement squeeze operations are not successful in completely shutting off flow of gas or fluids through the cement defects or channels.

Formations containing natural fractures, induced fractures or vugs present additional difficulty in cement squeezing. In these cases the matrix permeability is low and

the high effective permeability is due to the interconnected voids or fracture systems. In these formations, the cement slurry may move into the large voids or fracture system under low pressure differentials. Consequently, cement filtercake is not formed on the vug or fracture faces to immobilize the cement in the near wellbore area. The problem then becomes one of confining the remedial cement slurry to the near area of the wellbore so that squeeze pressure can be developed. Higher fluid loss cements which form filtercake more easily or slurries which set faster may be used in these cases, but they are limited because they still require differential pressure to form a cake. This differential pressure is difficult to develop in the highly conductive channels, and as a result, all the cement flows away from the near wellbore region resulting in an unsuccessful cement squeeze.

It is known to inject solutions into highly permeable formations, which at least partially plug the high permeability zones. Phenol-aldehyde resins and gels have heretofore been employed in permeability reducing and sand consolidating operations. Solutions of pre-catalyzed polyphenol-paraformaldehyde resin have also been employed to permanently plug ruptures or perforations in oil well casings. However, these prior art techniques are used as substitutes for cement squeeze operations and do not offer a solution to the above mentioned problems in cement squeeze operations. Prior art methods using resins or gels alone are ineffective to provide dependable, stable, long-term plugging of large channels or

perforations. Prior art methods using cement alone are ineffective to provide plugging or sealing of small channels or high permeability zones. Consequently, there exists a need in the art for a method to make the frequently used remedial cement squeeze technique effective in plugging channels and perforations in vuggy, fractured and highly permeable formations.

In the practice of the present invention, an improved method of remedial cement squeezing is provided to overcome the difficulties of cement squeezing in the formations discussed above. This improvement comprises a two-stage method of remedial cementing.

SUMMARY OF THE INVENTION

The present invention is directed to a two-stage method for remedial cementing of an area in a wellbore. The method comprises the steps of: a) injecting a phenolic-aldehyde gelling solution into an area wherein remedial cementing is to be performed such that a gel forms near the wellbore, and b) sequentially squeezing cement into the area. This method is useful to effectively seal perforations or areas in fractured, vuggy or highly permeable zones having large pore sizes as well as to block small channels in cement behind the casing resulting in an effective remedial cement squeezing operation.

In a preferred embodiment, the cement is squeezed into the area as the gel forms.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a method for remedial or squeeze cementing of a specific point in a well so that all perforations or channels behind the casing are filled to obtain a seal between the casing and the formation. This method overcomes the difficulty of cement squeezing in fractured, vuggy or highly permeable rock wherein the cement flows into the voids or highly permeable regions under low pressure differentials. In such formations, cement filtercake is prevented from being built up on the vug or fracture faces to seal the vug or fracture and the cement is therefore not confined to the near wellbore area. This method also provides an effective means for blocking small, hairline channels in cement behind the casing that cannot be reached with a conventional cement squeeze.

According to the present invention, a two-stage process is provided wherein a phenolic-aldehyde gelling solution is first injected into the area to be shut off in a wellbore. The gelling solution is prepared as is known in the art by adding any commercially available mixture of a phenolic resin and an aldehyde to water to which caustic has been added. The caustic acts as the catalist for the polymerization reaction which forms a stiff, i.e. highly viscous, impermeable gel. Rate of polymerization is controlled, as is known in the art, so that the solution will not stiffen in the wellbore.

The phenolic component may be one or more of any phenolic compounds such as phenol, resorcinol, catachol, and the like, as well as selected oxidized phenolic compounds such as 1, 4-benzoquinone and natural or modified tannins. The aldehyde may be either a monoaldehyde, such as formaldehyde and acetaldehyde, or a dialdehyde, such as glyoxal. Formaldehyde is the most preferred aldehyde. The aldehyde may also be generated in-situ by an aldehyde precusor, such as paraformaldehyde. The phenolic compound to aldehyde ratio may be any ratio suitable to form a stiff gel upon polymerization.

For purposes of this invention, the concentration of the phenolic resin and aldehyde mixture is from about 1 to about 50 weight percent of the gelling solution. Preferably, the concentration is from about 5 to about 30 weight percent, and most preferably from about 10 to about 20 weight percent.

The amount of gelling solution injected depends on the application and may be determined based on previous plugging treatments, formation permeability, and desired extent of plugging.

The gelling solution as injected preferably has a low viscosity (2-3 cp) and will invade small channels in the formation rock. The solution forms a time-controlled stiff gell that has a low density and tends to stay where it is placed.

The resin acts to seal the small channels, vugs, fractures or high permeability zones in the near wellbore region. The resin also forms a cushion for the second stage conventional cement squeeze. The phenolic-aldehyde gel is superior to other known resins because of its tolerance of high temperature and pH variations.

After a predetermined amount of gelling solution is injected, a conventional cement squeeze operation is performed. The various methods of remedial cementing are old and known by those skilled in the art. Although the gel may be allowed to stiffen before cement is injected, a water or other suitable spacer must be injected to displace the gelling solution from the perforations or other treated area prior to cement injection. It is therefore preferred that the cement squeeze take place as the gel stiffens so that the cement displaces the gelling solution. The gel forms a cushion so that pressure may be applied to the cement slurry for cement filtercake buildup and consequent sealing of the vugs, fractures and high permeability zones without loss of cement from the near wellbore region.

In another embodiment, a second treatment of the gelling solution may be injected prior to cement injection.

Example I

In order to illustrate the benefits of this invention, a field test was conducted to shut off water which was channeling through suspected fractures or channels behind the casing to the perforated interval in a well. The well was completed in a carbonate reef which is dolomitized and vugular in nature. The porosity is less than 9% and the permeability is in the Darcy range due to fractures and vugs. The oil production mechanism is bottom water drive. The well when initially completed at a first set of perforations produced 40-50 m^3 oil per day, but gradually started to produce large amounts of water.

Initially, the first set of perforations were cement squeezed and the well was completed 4 meters higher up with a second set of perforations. The production of oil went up to 35 m^3 per day and water production dropped to about 5 m^3 per day temporarily for a period of about two months. However, the oil production started to decline again and the well started to produce water at about 15 m^3 per day. At this time it was suspected that the water was coming to perforations either through vertical channels near the wellbore or through very fine channels in cement behind the casing.

The well was then treated in accordance with the present invention. The treatment consisted of pumping 10 m^3 of a 10% phenolformaldehyde gelling solution tagged with radioactive Indium 111, followed by 0.7 m^3 of class G cement through the retainer in the second set of perforations. Three days after the treatment, the cement was drilled out and the cemented interval held the pressure well. A gamma-ray log was run to trace the phenolformaldehyde gel distribution behind the casing. The gamma-ray log suggested that the gelling solution traveled 15m vertically. It is interesting to note that while the injected gelling solution only went 2m above the injected perforations, a substantial portion of it went into the formation at the treatment perforation depth as well as downward from the treatment perforations, past the lower previously cemented perforations, evidently through channels or voids in the near wellbore area.

The well was completed 2m higher at the gas oil contact at a third set of perforations. The well started production with a higher gas cut as expected, but five months after the treatment it produced largely oil and no water. The initial results suggest that gel blocked the water channels not blocked by the cement. Therefore, a two-stage treatment involving phenolformaldehyde gel followed by cement has been shown to work better than a cement squeeze alone.

Example II

A well completed near the top of a carbonate reef in a vugular, low pressure and fractured formation was treated in accordance with the present invention. The well was producing 22m^3 oil and 295m^3 water per day. To shut off the excessive water production, the existing perforations were treated with 24m^3 of radioactively tagged phenolformaldehyde gelling solution, followed by 2.4m^3 cement. Three days after the treatment, the cement was drilled out and pressure tested to 7MPa. The test indicated that the treated perforations were successfully shut off. The gamma ray log indicated 9m of gel placement vertically behind the casing. The well was then perforated just above the plugged perforations. Initial data indicates production of 55m^3 oil and 27m^3 water per day. This corresponds to a reduction of the water-oil-ratio from 14 to 0.5.

The preferred embodiments of the present invention have been described above. It should be understood that the foregoing description is intended only to illustrate certain preferred embodiments of the invention and is not intended to define the invention in any way. Other embodiments of the invention can be employed without departing from the full scope of the invention as set forth in the appended claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for remedial cementing of channels behind a well casing in a wellbore penetrating a subterranean formation comprising:

(a) injecting a phenolic-aldehyde gelling solution into an area wherein said remedial cementing is to be performed such that a gel forms near said wellbore; and

(b) sequentially squeezing cement into said area.

2. A process in accordance with claim 1 wherein said gelling solution comprises phenol and formaldehyde.

3. A process in accordance with claim 1 wherein said gelling solution comprises a phenolic compound and an aldehyde precursor such that aldehyde is formed in-situ.

4. A process in accordance with claim 3 wherein said aldehyde precursor is paraformaldehyde.

5. A process in accordance with claim 1 wherein said injection of gelling solution is followed by a second injection of gelling solution prior to said squeezing of cement.

6. A process in accordance with claim 1 wherein said cement squeeze is performed as said gel forms.

7. A process in accordance with claim 1 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 1 to about 50 weight percent of said gelling solution.

8. A process in accordance with claim 1 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 5 to about 30 weight percent of said gelling solution.

9. A process in accordance with claim 1 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 10 to about 20 weight percent of said gelling solution.

10. A process for remedial cementing of channels behind a well casing in a wellbore penetrating a subterranean formation comprising:

(a) injecting a phenolformaldehyde gelling solution, comprising a mixture of phenolic compound and aldehyde from about 10 to about 20 weight percent of said gelling solution, into an area wherein said remedial cementing is to be performed such that a gel forms near said wellbore; and

(b) sequentially squeezing cement into said area as said gel forms.

11. A process for remedial cementing of perforations in a wellbore penetrating a subterranean formation comprising:

(a) injecting a phenolic-aldehyde gelling solution into an area wherein said remedial cementing is to be performed such that a gel forms near said wellbore; and

(b) sequentially squeezing cement into said area.

12. A process in accordance with claim 11 wherein said gelling solution comprises phenol and formaldehyde.

13. A process in accordance with claim 11 wherein said gelling solution comprises a phenolic compound and an aldehyde precursor such that aldehyde is formed in-situ.

14. A process in accordance with claim 13 wherein said aldehyde precursor is paraformaldehyde.

15. A process in accordance with claim 11 wherein said injection of gelling solution is followed by a second injection of gelling solution prior to said squeezing of cement.

16. A process in accordance with claim 11 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 1 to about 50 weight percent of said gelling solution.

17. A process in accordance with claim 1 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 5 to about 30 weight percent of said gelling solution.

18. A process in accordance with claim 1 wherein said phenolic-aldehyde gelling solution comprises a mixture of a phenolic resin and an aldehyde from about 10 to about 20 weight percent of said gelling solution.

19. A process for remedial cementing of perforations in a wellbore penetrating a subterranean formation comprising:

(a) injecting a phenolformaldehyde gelling solution, comprising a mixture of phenolic compound and aldehyde from about 10 to about 20 weight percent of said gelling solution, into an area wherein said remedial cementing is to be performed such that a gel forms near said wellbore; and

(b) sequentially squeezing cement into said area as said gel forms.